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Shreve et al.

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(45) **Date of Patent: May 17, 2016**

(54) **METHOD, SYSTEM AND APPARATUS FOR AUTOMATIC CALIBRATION OF A NEEDLE VALVE DEVICE IN A PRESSURIZED FLOW SYSTEM**

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PCT Pub. Date: **Sep. 12, 2013**

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(Continued)

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See application file for complete search history.

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Assistant Examiner — Kevin Barss
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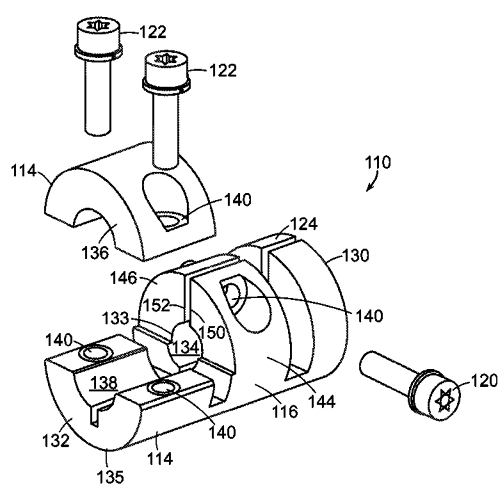
(57) **ABSTRACT**

Exemplary embodiments are directed to apparatus, systems and methods used in connection with a needle valve device operating in a pressurized flow system. The apparatus, systems and methods provide for automatic positioning of a needle relative to a seat in the needle valve device to provide consistent calibration with minimal user interaction after a maintenance event or upon a start-up of the pressurized flow system. The apparatus, systems and methods utilize a calibration collar secured to a shaft of an actuator within the needle valve device. The calibration collar includes one or more locking mechanism and a spring.

25 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

G01N 30/20	(2006.01)
G01N 30/32	(2006.01)
F16K 31/06	(2006.01)
B01D 15/40	(2006.01)

(52) **U.S. Cl.**

CPC ***G01N 30/20*** (2013.01); ***G01N 30/32*** (2013.01); *B01D 15/40* (2013.01); *Y10T 137/0486* (2015.04); *Y10T 137/6065* (2015.04)

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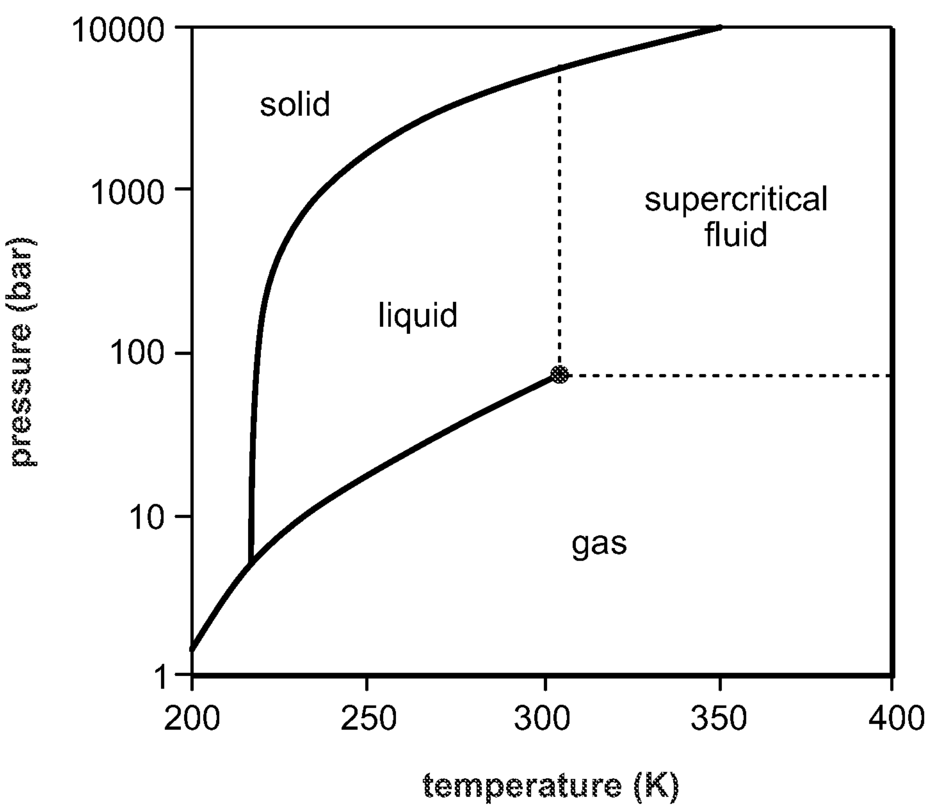
10000
1000
100
10
1
pressure (bar)
solid
liquid
supercritical
fluid
gas
200
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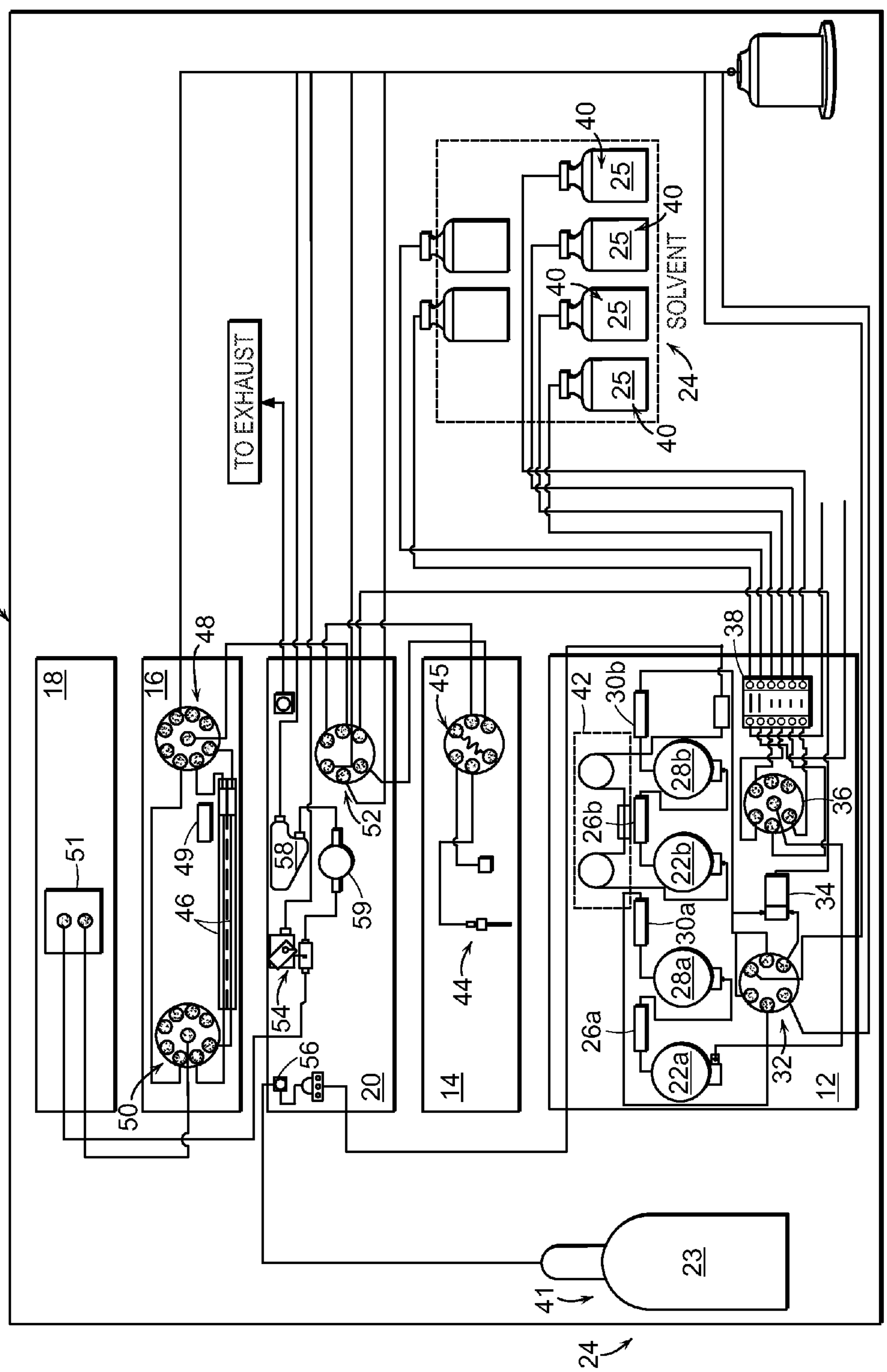
350
400
temperature (K)

FIG. 1



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TO EXHAUST
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FIG. 2

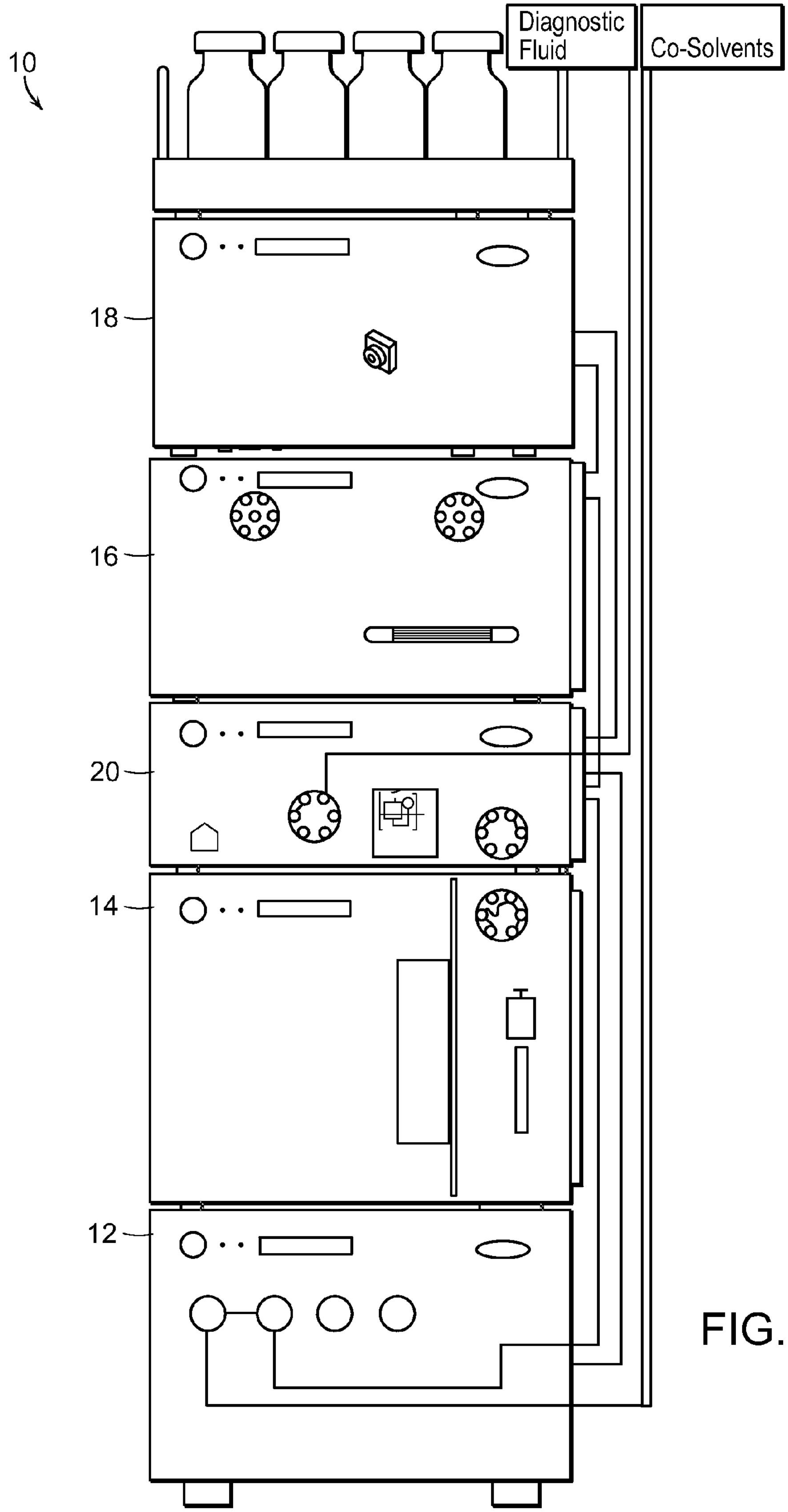


FIG. 3

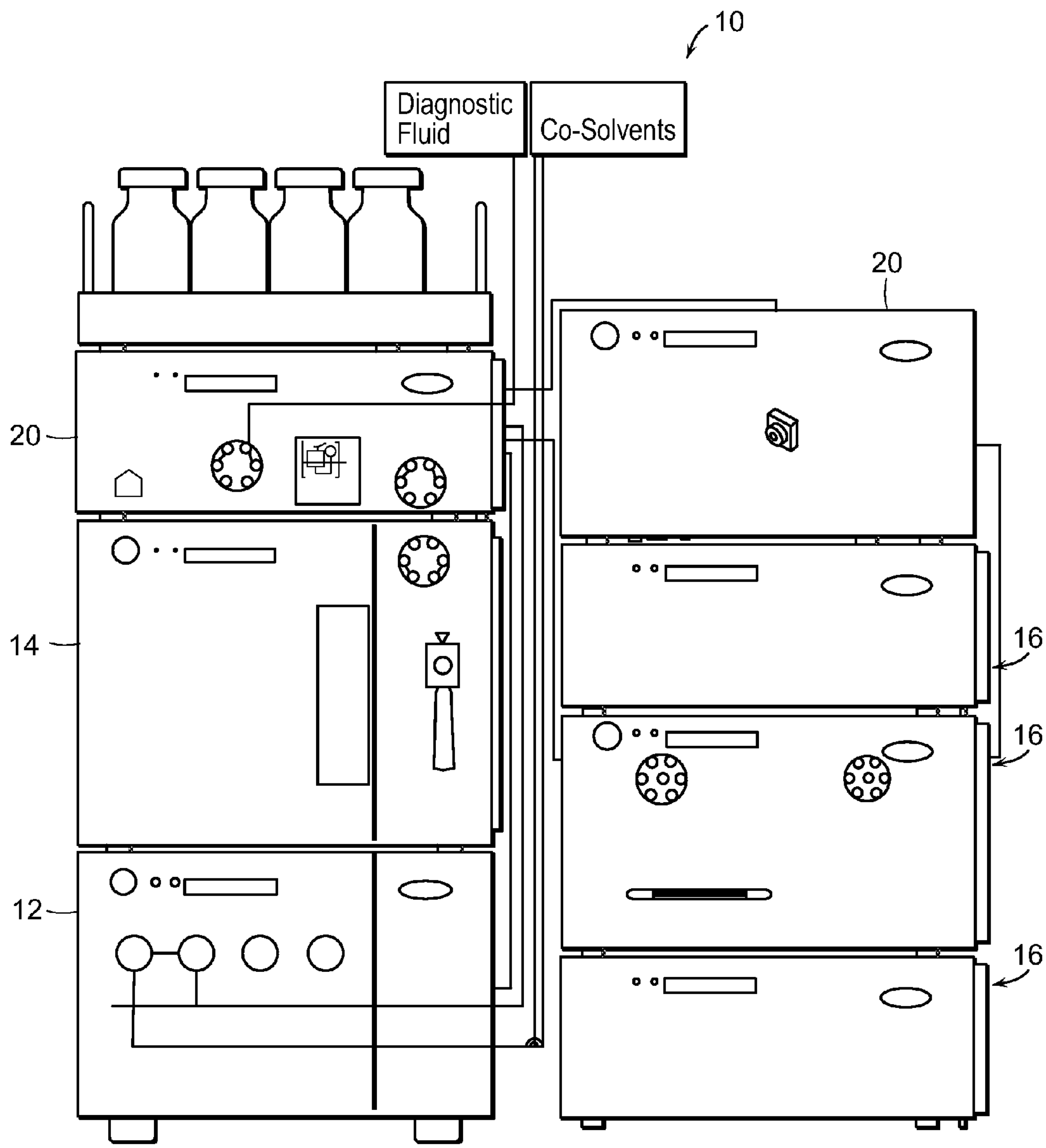
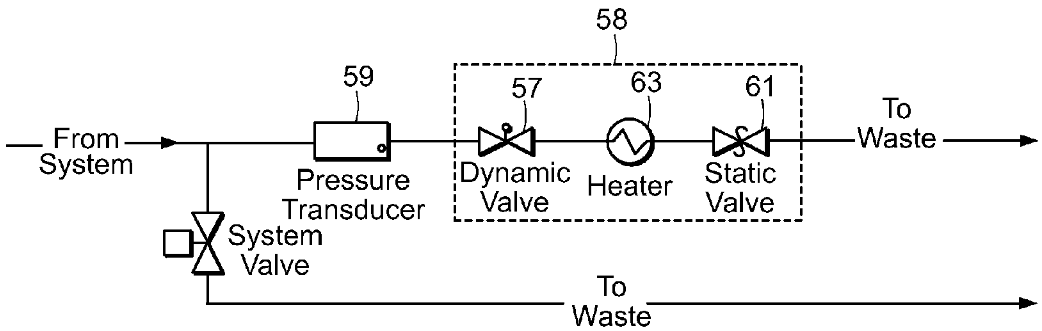


FIG. 4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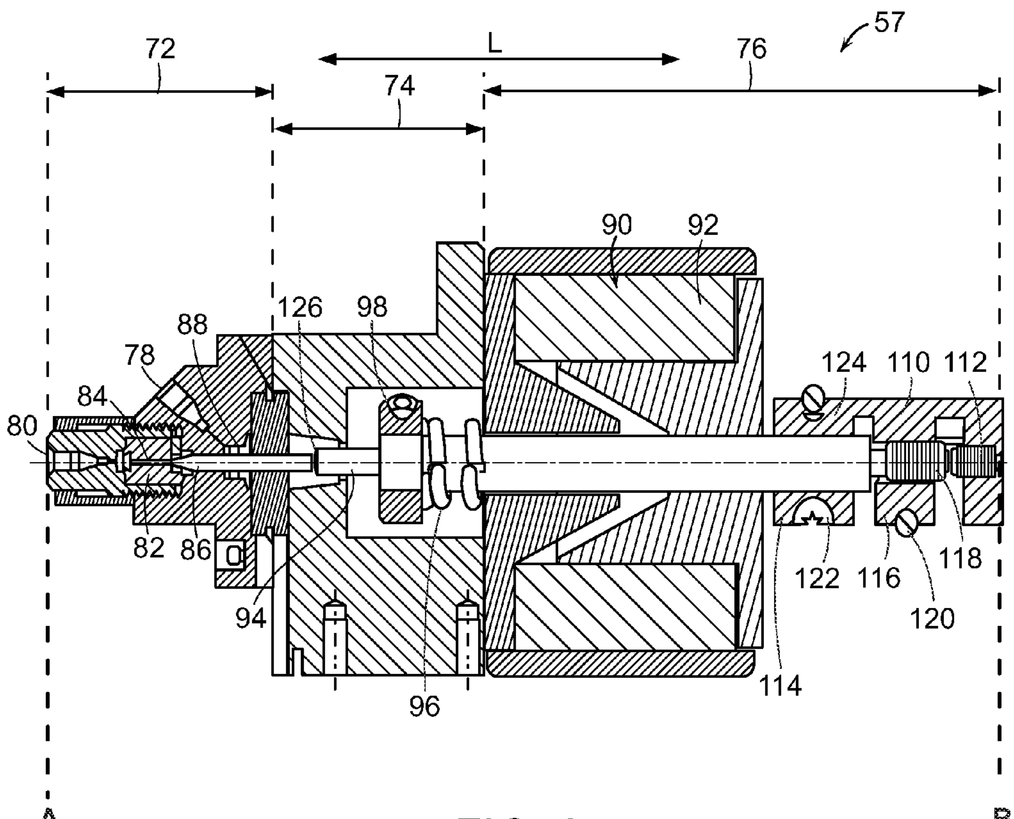
From System
Pressure Transducer
Dynamic Valve
Heater
Static Valve
To Waste
System Valve
To Waste

FIG. 5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A
B

FIG. 6

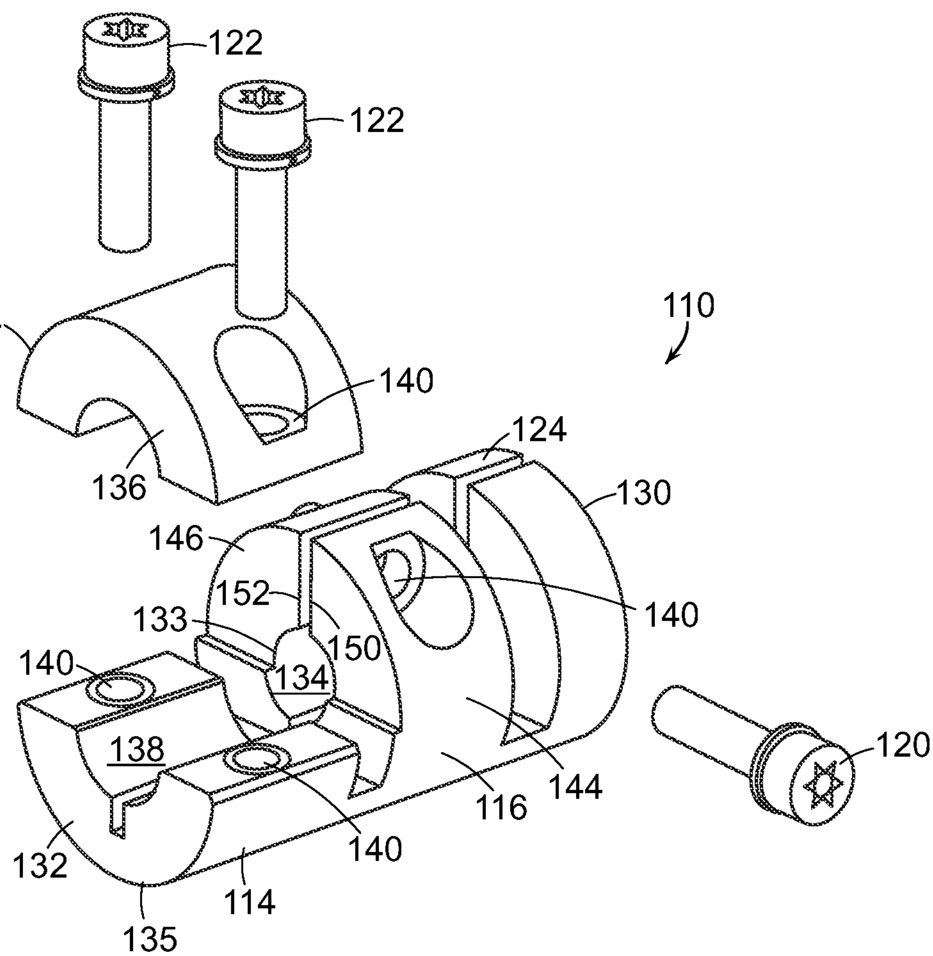

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FIG. 7A

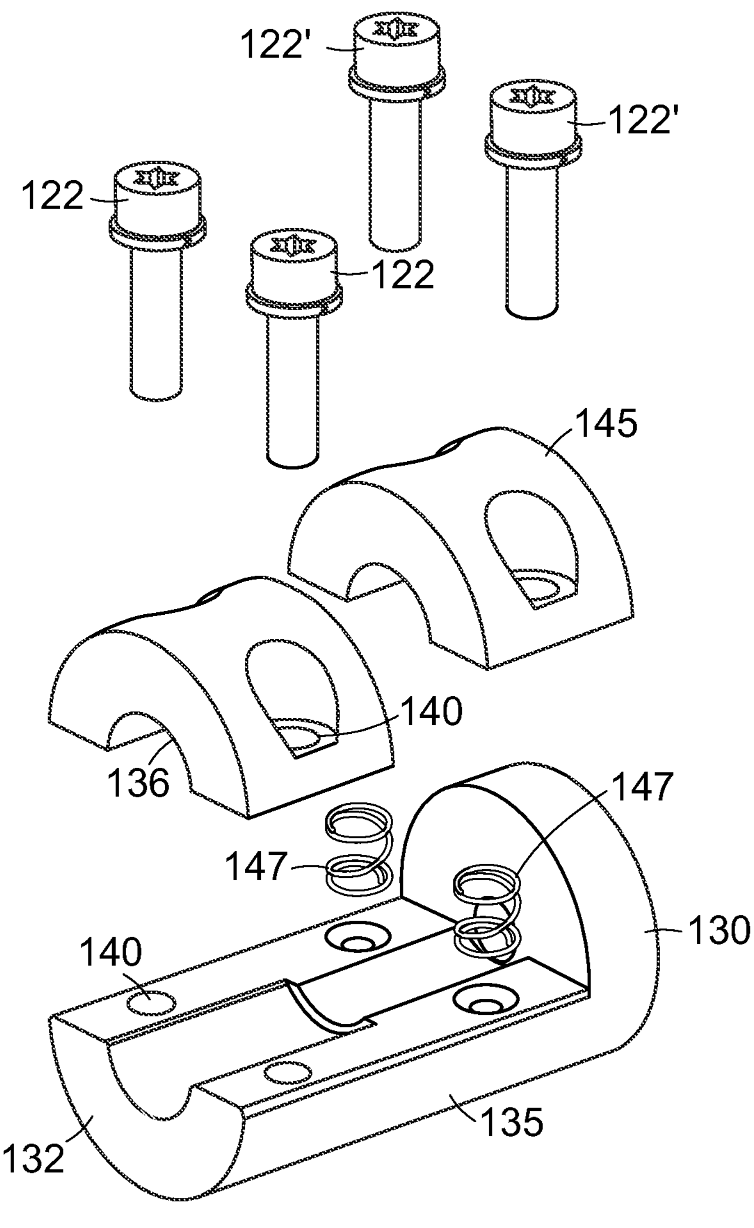

FIG. 7B

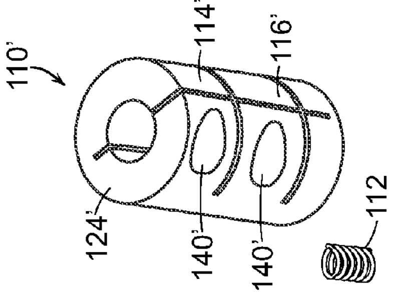

FIG. 8

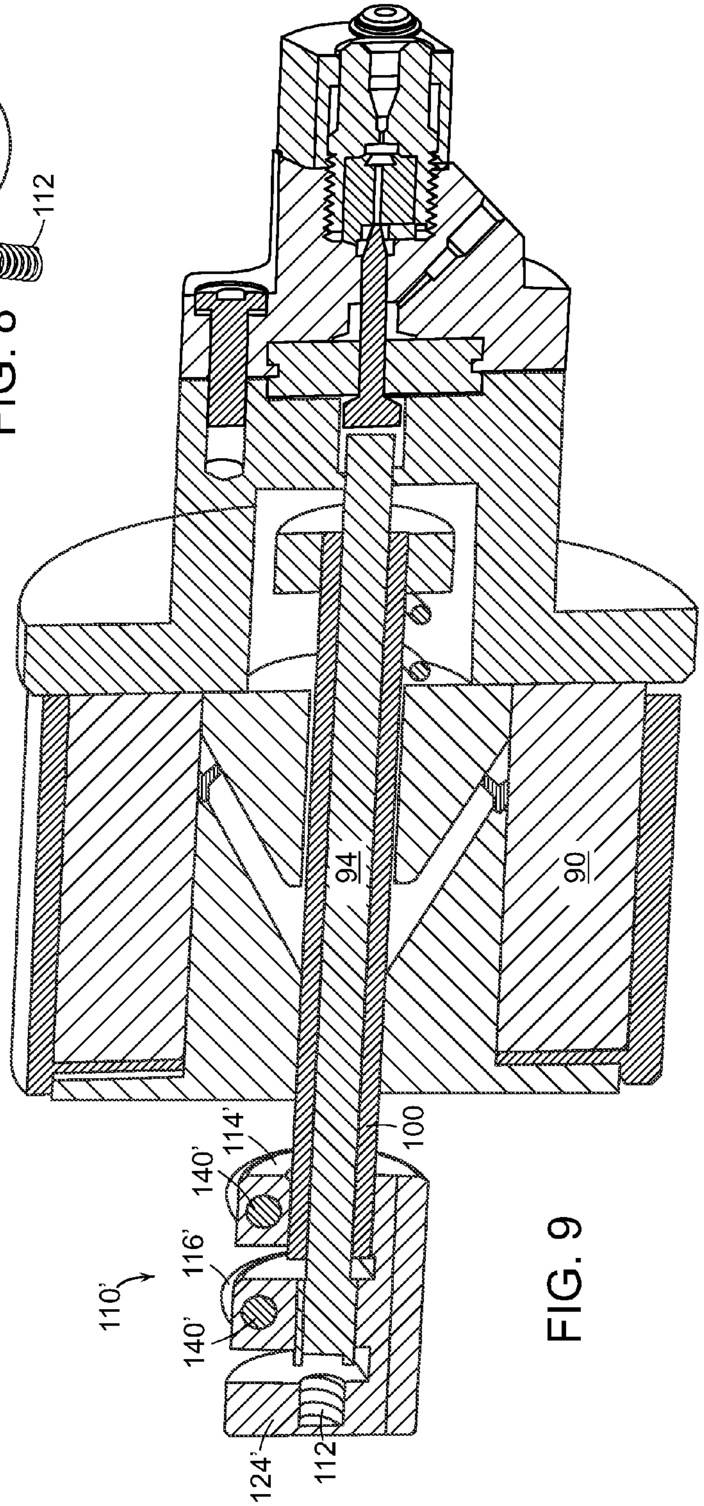

FIG. 9

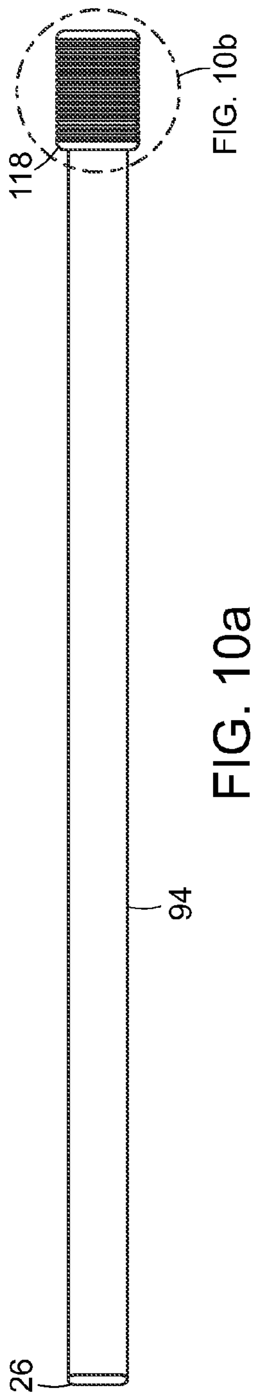

FIG. 10a

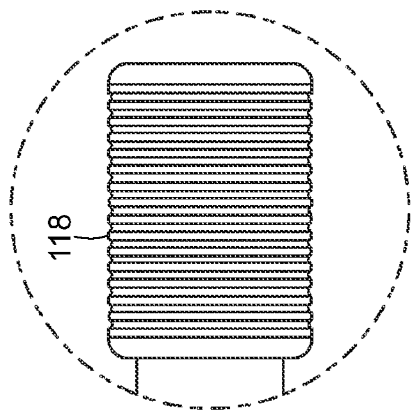

FIG. 10b

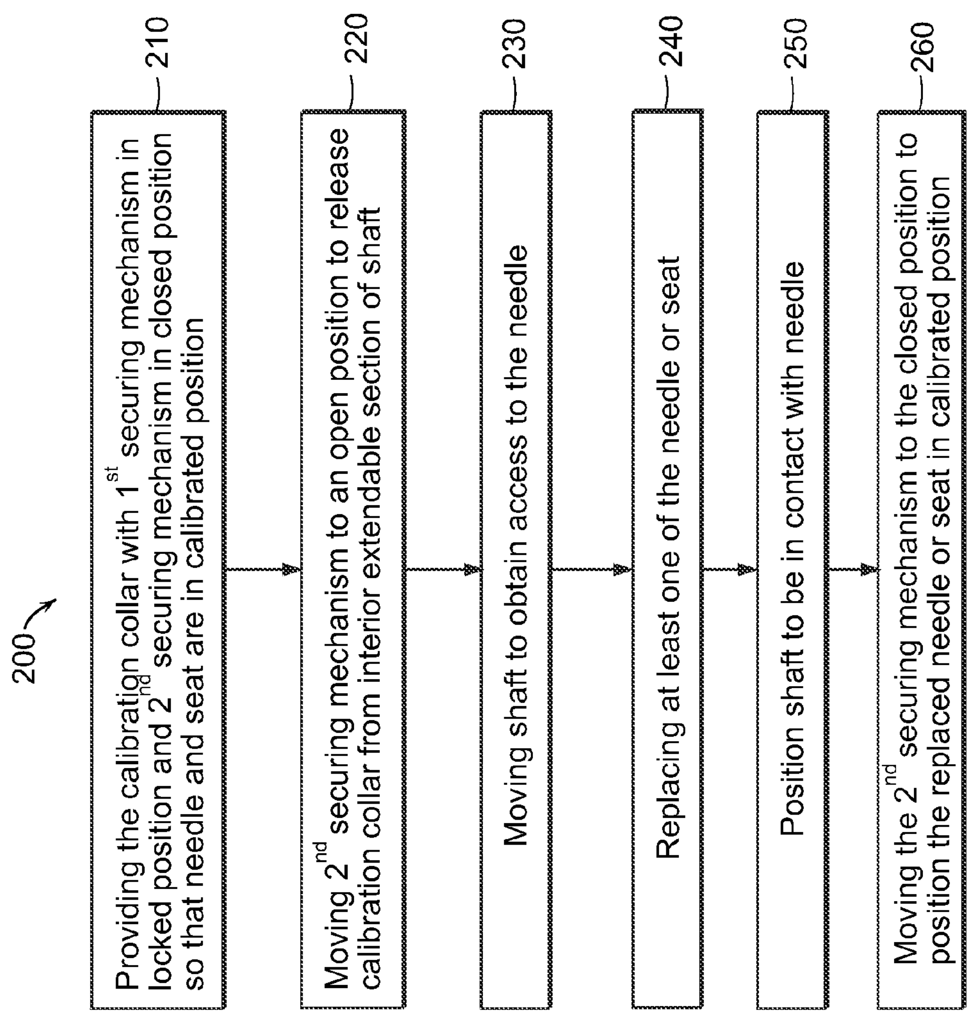
200
Providing the calibration collar with 1st securing mechanism in locked position and 2nd securing mechanism in closed position so that needle and seat are in calibrated position
210
Moving 2nd securing mechanism to an open position to release calibration collar from interior extendable section of shaft
220
Moving shaft to obtain access to the needle
230
Replacing at least one of the needle or seat
240
Position shaft to be in contact with needle
250
Moving the 2nd securing mechanism to the closed position to position the replaced needle or seat in calibrated position
260

FIG. 11

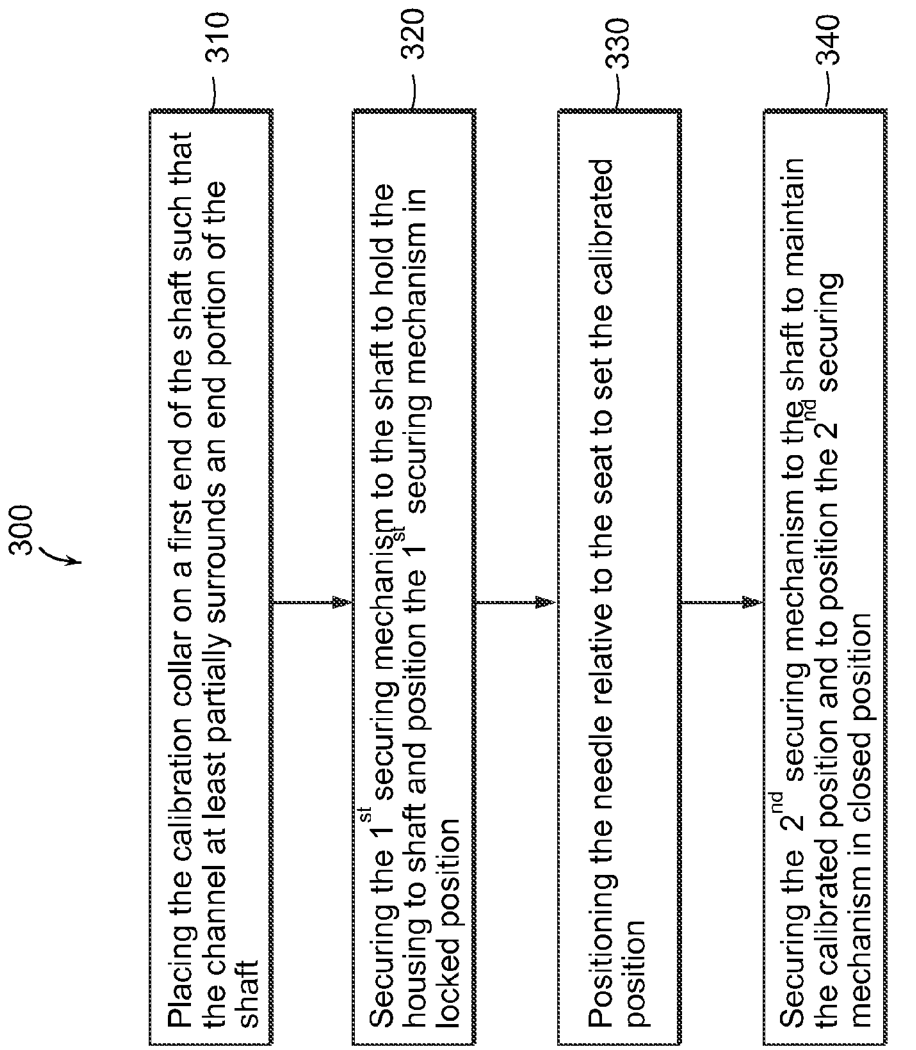
300
310
Placing the calibration collar on a first end of the shaft such that the channel at least partially surrounds an end portion of the shaft
320
Securing the 1st securing mechanism to the shaft to hold the housing to shaft and position the 1st securing mechanism in locked position
330
Positioning the needle relative to the seat to set the calibrated position
340
Securing the 2nd securing mechanism to the shaft to maintain the calibrated position and to position the 2nd securing mechanism in closed position

FIG. 12

METHOD, SYSTEM AND APPARATUS FOR AUTOMATIC CALIBRATION OF A NEEDLE VALVE DEVICE IN A PRESSURIZED FLOW SYSTEM

RELATED APPLICATIONS

This application is a National Stage Application of International Application No. PCT/US2013/029580, filed Mar. 7, 2013, which claims priority to U.S. Provisional Application No. 61/607,930, filing date Mar. 7, 2012. Each of the foregoing applications is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to needle valve devices and associated apparatus, systems and methods and, in particular, to needle valve devices and associated apparatus, systems and methods that allow for automatic calibration of a position of a needle within a needle valve device used in a pressurized flow application, such as, for example CO_2-based chromatography.

BACKGROUND

Chromatographic techniques are important tools for the identification and separation of complex samples. The basic principle underlying chromatographic techniques is the separation of a mixture into individual components by transporting the mixture in a moving fluid through a retentive media. The moving fluid is typically referred to as the mobile phase and the retentive media is typically referred to as the stationary phase. The separation of the various constituents of the mixture is based on differential partitioning between the mobile and stationary phases. Differences in components' partition coefficient result in differential retention on the stationary phase, resulting in separation.

Conventionally, the methods of choice for chromatographic separations have been gas chromatography (GC) and liquid chromatography (LC). One major difference between GC and LC is that the mobile phase in GC is a gas, whereas the mobile phase in LC is a liquid. For example, in GC, a supply of inert carrier gas (mobile phase) is continually passed as a stream through a heated column containing porous sorptive media (stationary phase). A sample of the subject mixture is injected into the mobile phase stream and passed through the column, where separation of the mixture is primarily due to the differences in the volatile characteristics of each sample component at the temperature of the column. A detector, positioned at the outlet end of the column, detects each of the separated components as they exit the column. Although GC is typically a sensitive method of analysis, the high temperatures required in GC make this method unsuitable for high molecular weight biopolymers or proteins (heat will denature them), frequently encountered in biochemistry.

Conversely, LC is a separation technique in which the mobile phase is a liquid and does not require volatilization of the sample. Liquid chromatography that generally utilizes small packing particles and moderately high pressure is referred to as high-performance liquid chromatography (HPLC); whereas liquid chromatography that generally utilizes very small packing particles and high pressure is referred to as ultra-high performance liquid chromatography (UHPLC). In HPLC and UHPLC the sample is forced by a liquid at high pressure (the mobile phase) through a column that is packed with a stationary phase composed of irregularly or spherically shaped particles, a porous monolithic layer, or a porous membrane.

Because LC uses liquid as the mobile phase, LC techniques are capable of analyzing higher molecular weight compounds and, in some cases, LC can be used to prepare large scale batches of purified protein(s). However, in contrast, GC techniques are typically more sensitive and readily allow for the separation of single chiral materials. Thus, GC has conventionally been used to isolate and determine the relative purity of a chiral compound, e.g., by determining the enantiomeric excess (% ee) or the diastereomeric excess (% de) of a particular sample. As with most chromatographic techniques, the limiting factor in both GC and LC has been the ability to obtain and/or reproduce pure sample separations, each of which are typically dependent on the apparatus, methods, and conditions employed, e.g., flow rate, column size, column packing material, solvent gradient, etc.

Supercritical Fluid Chromatography is another chromatographic technique, which has typically been used in preparative applications. For every liquid substance there is a temperature above which it can no longer exist as a liquid, no matter how much pressure is applied. Likewise, there is a pressure above which the substance can no longer exist as a gas no matter how much the temperature is raised. These points are called the supercritical temperature and supercritical pressure, and define the boundaries on a phase diagram for a pure substance (FIG. **1**). At this point, the liquid and vapor have the same density and the fluid cannot be liquefied by increasing the pressure. Above this point, where no phase change occurs, the substance acts as a supercritical fluid (SF). Thus, SF can be described as a fluid obtained by heating above the critical temperature and compressing above the critical pressure. There is a continuous transition from liquid to SF by increasing temperature at constant pressure or from gas to SF by increasing pressure at constant temperature.

The term SFC, while typically standing for Supercritical Fluid Chromatography, does not require or mean that supercritical conditions are obtained during or maintained throughout the separation. That is, columns do not have to be always operated in the critical region of the mobile phase. For example, in the event that the mobile phase includes a modifier (e.g., CO_2 and methanol as a modifier), the mobile phase is often in its subcritical region (e.g., a highly compressed gas or a compressible liquid rather than a supercritical fluid). In fact, as Guiochon et al note in section 2.3 of their review article entitled "Fundamental challenges and opportunities for preparative supercritical fluid chromatography" Journal of Chromatography A, 1218 (2011) 1037-1114: "It is obvious that SFC has very often been and still is run under subcritical conditions." Thus, the term SFC is not limited to processes requiring supercritical conditions.

Because SFC typically uses CO_2, SFC processes are inexpensive, innocuous, eco-friendly, and non-toxic. There is typically no need for the use of volatile solvent(s) (e.g., hexane). Finally, the mobile phase in SFC processes (e.g., CO_2 together with any modifier/additive as a SF, highly compressed gas, or compressible liquid) typically have higher diffusion constants and lower viscosities relative to liquid solvents. The low viscosity means that pressure drops across the column for a given flow rate is greatly reduced. The increased diffusivity means longer column length can be used.

SUMMARY

Exemplary embodiments of the present technology are directed to apparatus, systems and methods for automatically setting a position of a needle in a needle valve device used in a pressurized flow system. Needles and/or their associated seats in pressurized flow systems can wear out over time and can require replacement or reconfiguration for a different application. Due to tolerances needed for adequate pressure control, the positioning of the needle relative to the seat is generally calibrated after a maintenance event or prior to a start-up condition. In embodiments of the present technology, mechanical means, such as, for example, springs and locking mechanisms are utilized to automatically set (e.g., mechanically set) the position of the needle in a needle valve device. As a result, little or no interaction from a user is needed to calibrate a needle valve device upon start-up and/or after maintenance of the needle valve device. Embodiments of the needle valve device include pressure regulators in pressurized flow systems. Embodiments of the pressurized flow system can be implemented as a CO_2-based chromatography system in which the mobile phase is passed through a stationary phase and sample components of a sample injected into the mobile phase are separated and one or more characteristics of the sample components are detected.

In accordance with embodiments of the present disclosure, calibration collars or apparatus for automatically setting a position of a needle to a seat in a pressurized flow system including an actuator positioned to drive the needle relative to the seat are disclosed. The actuator includes a shaft including an exterior liner and an interior extendable section. The calibration collar includes a housing, a first securing mechanism, a second securing mechanism, and a spring. The housing of the calibration collar includes a first end and a second end and the housing defines a channel sized to accept at least a portion of the shaft of the actuator. The first securing mechanism of the calibration collar is positioned at the second end of the housing and surrounds the channel. The first securing mechanism, when in a locked position, holds the housing to the exterior liner of the shaft. The second securing mechanism is independent of the first securing mechanism. The second securing mechanism, when in a closed position, grips at least a portion of an external perimeter surface of the interior extendable section of the shaft to clamp the housing to the shaft. The spring of the calibration collar is disposed at least partially in the first end of the housing and extends into the channel to apply a known load on the shaft when the shaft is seated in the housing.

Embodiments of the above exemplary calibration collars or apparatus can include one or more of the following features. In some embodiments, the second securing mechanism is positioned between the first securing mechanism and the first end of the housing. In embodiments, the first and/or second securing mechanism is a clamp. In certain embodiments, the first securing mechanism and/or the second securing mechanism clamp includes a base portion integrally formed with the housing and a top portion secured to the base portion with two fasteners, e.g., screws. In some embodiments, the second securing mechanism clamp includes a first portion integrally formed with the housing and having a first free end and a second portion also integrally formed with the housing and having a second free end, wherein the second free end is opposite of the first free end and the first and second portions are secured together with a fastener. The housing can be formed of metal. In some embodiments, the housing is formed at least in part of stainless steel. In other embodiments, the housing is formed at least in part of aluminum. Other metals, alloys and combinations of materials are also possible. Embodiments can also include a textured housing for facilitating gripping between the actuator shaft and the calibration collar. For example, one or more embodiments include a surface (or at least a portion of a surface) of the housing defining the channel with a texture applied. The textured surface facilitates gripping of at least a portion of an external perimeter surface of the interior extendable section of the shaft of the actuator when the second securing mechanism is in a closed position. The texture applied to the surface or at least portion of the surface of the housing can include one or more of radial grooves, raised bumps, or raised ribs. In embodiments, the second securing mechanism is an electromechanical locking assembly. The electromechanical locking assembly can automatically place the second securing mechanism in the closed position upon start-up of the device and/or after a maintenance event.

In accordance with embodiments of the present technology, systems including the calibration collar attached to an actuator shaft of a needle valve device are disclosed. The calibration collar includes one or more locking mechanisms and a spring to mechanically position the needle of the needle valve device in relation to the seat with little to no interaction from a user. In some embodiments, the calibration collar is implemented as the calibration collar described above. The system can be used in a pressurized flow application, such as, for example, CO_2-based chromatography and provides consistent calibration of the needle to the seat at each start-up event.

In accordance with embodiments of the present technology, exemplary methods of replacing at least one of a needle or seat in a pressurized flow device are disclosed. Embodiments of the exemplary methods include a number of steps. First, the method includes providing a calibration collar (e.g., one of the exemplary calibration collars described herein) with the first securing mechanism in the locked position and the second securing mechanism in the closed position to secure and grip the calibration collar to the shaft of the actuator in an operating position in which the needle and the seat are in a calibrated position. Next, the method includes moving the second securing mechanism from the closed position to the open position to release the grip of the calibration collar from the interior extendable section of the shaft. The method also includes moving the shaft to obtain access to the needle, replacing at least one of the needle or seat; and positioning the shaft to be in physical contact with an end of the needle or a replacement needle. Once the shaft is in physical contact with the needle (or replacement needle), the method includes the step of moving the second securing mechanism from the open position to the closed position to grip the interior extendable section of the shaft and position the replaced needle or seat in the calibrated position.

Embodiments of the above exemplary methods can include one or more of the following features. In some embodiments, moving the second securing mechanism from the closed to the open position includes releasing a clamping mechanism, such as, for example loosening a fastener or electromechanically releasing an electromechanical clamp. In embodiments, moving the second securing mechanism from the open position to the closed position includes activating a clamping mechanism, such as, for example, tightening a fastener or activating an electromechanical clamp to close. In some embodiments, electromechanically releasing or activating of the second securing mechanism occurs automatically (e.g., without user interaction). In embodiments, the electromechanically activating the second securing mechanism occurs automatically upon a start-up condition.

In accordance with embodiments of the present technology, exemplary methods of setting and maintaining a calibrated position between a needle and a seat in a pressurized flow system are disclosed. In general, the pressurized flow system can be any type of pressurized flow system, such as, for example, a CO_2-based chromatography system. In addition, the pressurized flow system includes an actuator positioned to drive the needle relative to the seat. Embodiments of these exemplary methods include placing the calibration collar (e.g., one of the exemplary calibration collars described herein) on a first end of the shaft of the actuator such that the channel defined in the housing of the calibration collar at least partially surrounds an end portion of the shaft. The methods also include a step of securing the first securing mechanism of the calibration collar to the shaft to hold the housing to the shaft and to position the first securing mechanism in the locked position. The methods further include a step of positioning the needle relative to the seat to set the calibrated position. The methods also include a step of positioning a second end of the shaft of the actuator to be in physical contact with an exposed end of the needle; and securing the second securing mechanism of the calibration collar to the shaft to grip the external perimeter surface of the extendable section of the shaft to maintain the calibrated position and to position the second securing mechanism in the closed position.

Embodiments of the above exemplary methods can include additional features. For example, embodiments can include additional steps in which the grip of the calibration collar is released so that the shaft of the actuator can be displaced (e.g., shaft moved for maintenance purposes, such as, for example, replacement of needle or seat) without the need for recalibration. For example, methods can further include moving the second securing mechanism from the closed position to the open position to release the grip of the calibration collar from the shaft; moving the second end of the shaft to obtain access to the needle (e.g., obtain access to the needle for maintenance/replacement purposes); positioning the second end of the shaft to be in physical contact with the exposed end of the needle (e.g., reposition shaft after completing maintenance/replacement); and moving the second securing mechanism from the open position to the closed position to grip the shaft and to return the needle and the seat to the calibrated position.

The exemplary apparatus, calibration collars, systems, and methods of the present disclosure provide numerous advantages. For example, by incorporating one or more of the exemplary apparatus, calibration collars, systems or methods of the present disclosure into a pressurized flow system including a needle valve device, consistent needle calibration is achieved at, for example, start-up and/or after maintenance events. Consistent needle calibration allows for consistent behavior, which ultimately provides better separation results in chromatographic applications. In addition to providing consistent calibration, the exemplary apparatus, calibration collars, systems and methods provide increases in efficiency and minimization of maintenance time. That is, the apparatus, calibration collars, systems and methods provide an automatic or mechanically self-calibrating needle valve that simplifies maintenance events by limiting or eliminating user interaction (e.g., minimizes or eliminates decisions or calibration positioning by the user or controlling software) to recalibrate the position of the needle relative to the seat in the field after maintenance events.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages provided by the present disclosure will be more fully understood from the following description of exemplary embodiments when read together with the accompanying drawings, in which:

FIG. **1** is an exemplary graph of the physical state of a substance in relation to a temperature and pressure associated with the substance;

FIG. **2** is a block diagram of an exemplary pressurized flow system;

FIG. **3** is a block diagram of an exemplary arrangement of an embodiment of the system of FIG. **2**;

FIG. **4** is a block diagram of another exemplary arrangement of an embodiment of the system of FIG. **2**;

FIG. **5** is a flow diagram of a mobile phase through a system manager portion of the an exemplary embodiment of the pressurized flow system;

FIG. **6** is a cross-sectional view of a valve assembly for an exemplary dynamic pressure regulator in an exemplary embodiment of the pressurized system;

FIG. **7**A is an exploded perspective view of an exemplary embodiment of a calibration collar according to the present disclosure;

FIG. **7**B is an exploded perspective view of another exemplary embodiment of a calibration collar according to the present disclosure;

FIG. **8** is a perspective view of another exemplary embodiment of the calibration collar according to the present disclosure; in this view the calibration collar is shown without fasteners;

FIG. **9** is a cross-sectional view of another exemplary dynamic pressure regulator; in this view the dynamic pressure regulator includes the calibration collar of FIG. **8**;

FIGS. **10**(*a*)-(*b*) are side and detailed views of an exemplary embodiment of an interior portion of a shaft of an actuator included in the pressure regulator shown in FIG. **6**;

FIG. **11** is a flowchart illustrating an exemplary method of using the calibration collar of the present disclosure to maintain a calibrated position between a needle and a seat after a maintenance event; and

FIG. **12** is a flowchart illustrating an exemplary method of using the calibration collar to set and maintain a calibrated position between a needle and a seat in a pressurized flow system.

DESCRIPTION OF EXEMPLARY EMBODIMENT

SFC can be adapted as a hybrid between HPLC and GC apparatuses, where the predominant modification is replacement of either the liquid or gas mobile phase with a supercritical fluid (or near supercritical fluid) mobile phase, such as with CO_2. In SFC, the mobile phase is initially pumped as a liquid or gas and is brought into the supercritical region by heating or pressurizing the mobile phase above its supercritical temperature/pressure prior to entry into a column. As the mobile phase passes through an injection valve, the sample is introduced into the supercritical stream, and the mixture is then transferred into a column. The mixture passes through the column (at supercritical or liquid state) and into the detector.

In general, the mobile phase in SFC processes have the ability to act both as substance carriers (like the mobile phases in GC), and dissolve substances readily (like the solvents used in LC). In addition to generally having lower viscosities and better diffusion profiles similar to those of certain gases, the mobile phase in SFC processes also generally have high densities and dissolving capacities similar to those of certain liquids. For example, SFs' high densities (0.2-0.5 gm/cm^3) provide for their remarkable ability to dissolve large, non-volatile molecules, e.g., supercritical or near supercritical CO_2 readily dissolves n-alkanes, di-n-alkyl phthalates, and polycyclic and aromatic compounds. Since the diffusion of solutes in a SFC mobile phase is about ten times greater than that in liquids (about three times less than in gases), this results in a decrease in resistance to mass transfer in the column and allows for fast high resolution separation. Also, the solvation strength of the mobile phase in SFC processes is directly related to the fluid density. Thus, the solubility of solids can be easily manipulated by making slight changes in temperatures and pressures.

Another important property of the mobile phase in SFC processes is that it provides high resolution chromatography at much lower temperatures. For example, an analyte dissolved in supercritical CO_2 can be recovered by reducing the pressure and allowing the sample to evaporate under ambient laboratory conditions. This property is useful when dealing with thermally unstable analytes, such as high molecular weight biopolymers or proteins.

The combination of one or more mechanical or column changes to an SFC instrument (e.g., a CO_2-based chromatography instrument) coupled with the inherent properties of the SFC itself, allows for the separation of both chiral and achiral compounds, and has become increasingly predominant in the field of preparatory separations for drug discovery and development. Despite considerable advances in SFC technology, there is a need to develop innovative methods and apparatuses that improve the use of SFC. Controlling and stabilizing the pressure in an SFC instrument by one or more process and/or improving one or more of the instrumental characteristics of the system, may lead to, amongst others, improved compound separation and efficiency.

For example, better resolution and increased flow rate would decrease cycle times (i.e., shorter cycle times) and allow for improved separation of both chiral and achiral compounds, and lead to an overall increase in laboratory efficiency; increased speed and throughput would decrease the amount of solvent and cost(s) associated with SFC; and the ability to further integrate SFC with other detection methods, such as Mass Spectrometry (MS), Flame Ionization Detectors (FID), and Ultraviolet/Visible (UV) detectors, would improve the mainstream use of SFC using a mobile phase including CO_2 as an eco-friendly, yet effective, alternative method for the fast, complete, and sensitive analysis of analytes.

Exemplary embodiments of the present disclosure are directed to automatically setting a position of a needle in a needle valve device used in a pressurized flow system, such as, for example a CO_2-based chromatography system. Exemplary embodiments can implement one or more apparatus, systems or methods for setting the position of a needle relative to a seat in a needle valve device to provide consistent calibration with minimal user interaction after a maintenance event or upon a start-up of the pressurized flow system (e.g., calibration of the needle valve device in the field after a maintenance event). As an example, in one embodiment, a user performing maintenance on the needle valve device merely needs to open one of two securing mechanisms on a calibration collar attached to the shaft of an actuator to access the needle. To provide consistent calibration and to place the needle back into a calibrated position with a seat after maintenance, the user merely has to place the shaft in physical contact with the needle and close the securing mechanism. That is, the user does not have to recalibrate the position of the needle to the seat through the use of manual or computer-assisted calibration techniques, rather the mechanical collar locked to the shaft returns the needle to the calibrated position automatically (e.g., self calibration).

As used herein, the terms "downstream" and "upstream" refer to relative locations in a system flow, wherein upstream refers to being associated with an earlier portion of the system flow compared to later portion of the system flow and downstream refers to being associated with a later portion of the system flow compared to an earlier portion of the system flow.

FIG. **2** is a block diagram of an exemplary pressurized flow system, which in the present embodiment is implemented as a CO_2-based chromatography system **10** (hereinafter "system **10**"). While the present embodiment is illustrative of a CO_2-based chromatography system operated at or near supercritical conditions, those skilled in the art will recognize that exemplary embodiments of the present disclosure can be implemented as other pressurized flow systems and that one or more system components of the present disclosure can be implemented as components of other pressurized systems. System **10** can be configured to detect sample components of a sample using chromatographic separation in which the sample is introduced into a mobile phase that is passed through a stationary phase. System **10** can include one or more system components for managing and/or facilitating control of the physical state of the mobile phase, control of the pressure of system **10**, introduction of the sample to the mobile phase, separation of the sample into components, and/or detection of the sample components, as well as venting of the sample and/or mobile phase from system **10**.

In the present embodiment, system **10** can include a solvent delivery system **12**, a sample delivery system **14**, a sample separation system **16**, a detection system **18** (e.g., a PDA detector), and a system/convergence manager **20**. In some embodiments, the system components can be arranged in one or more stacks. As another example, in one embodiment, the system components of system **10** can be arranged in a single vertical stack (FIG. **3**). The system components of the system **10** can be arranged in multiple stacks (FIG. **4**). Those skilled in the art will recognize that other arrangements of the components of system **10** are possible. Furthermore, while embodiments of system **10** have been illustrated as including system components **12**, **14**, **16**, **18**, and **20**, those skilled in the art will recognize that embodiments of system **10** can be implemented as a single integral unit, that one or more components can be combined, and/or that other configurations are possible.

The solvent delivery system **12** can include one or more pumps **22*a*** and **22*b*** configured to pump one or more solvents **24**, such as mobile phase media **23** (e.g., carbon dioxide) and/or modifier media **25** (i.e., a co-solvent, such as e.g., methanol, ethanol, 2-methoxyethanol, isopropyl alcohol, or dioxane), through the system **10** at a predetermined flow rate. For example, the pump **22*a*** can be in pumping communication with the modifier media **25** to pump the modifier media **25** through the system **10**, and the pump **22*b*** can be in pumping communication with the mobile phase media **23** to pump the mobile phase media **23** through the system **10**. An output of the pump **22*a*** can be monitored by a transducer **26*a*** and an output of the pump **22*b*** can be monitored by a transducer **26*b***. The transducers **26*a*** and **26*b*** can be configured to sense the pressure and/or flow rate associated with the output of the solvent **24** from the pumps **22*a*** and **22*b***, respectively. Each pump **22*a*** and/or **22*b*** further includes a pump control valve configured to be actuated into, e.g., a flow position, a block position, a vent position, and the like.

The outputs of the pumps **22*a*** and **22*b*** can be operatively coupled to an input of accumulators **28*a*** and **28*b***, respectively. The accumulators **28*a*** and **28*b*** are refilled by the outputs of the pumps **22*a*** and **22*b***, respectively, and can contain an algorithm to reduce undesired fluctuations in the flow rate and/or pressure downstream of the pumps **22***a* and **22***b*, which can cause detection noise and/or analysis errors on the system **10**. An output of the accumulator **28***a* can be monitored by a transducer **30***a* and an output of the accumulator **28***b* can be monitored by a transducer **30***b*. The transducers **30***a* and **30***b* can be configured to sense pressure and/or flow rate at an output of the accumulators **28***a* and **28***b*, respectively. The outputs of the accumulators **28***a* and **28***b* can be operatively coupled to a multiport valve **32**, which can be controlled to vent the solvent **24** (e.g., mobile phase media **23** and modifier media **25**) being pumped by the pumps **22***a* and **22***b* and/or to output the solvent **24** to a mixer **34**. The mixer **34** can mix the modifier media **25** and the mobile phase media **23** output from the pumps **22***a* and **22***b*, respectively (e.g., after first passing through the accumulators **28***a* and **28***b*) and can output a mixture of the mobile phase media **23** and the modifier media **25** to form a solvent stream (i.e., mobile phase) that flows through the system **10**. The output of the mixer **34** can be operatively coupled to the system/convergence manager **20** as discussed in more detail below.

In exemplary embodiments, the solvent delivery system **12** can include a multiport solvent selection valve **36** and/or a degasser **38**. The solvent selection valve **36** and/or the degasser **38** can be operatively disposed between an input of the pump **22***a* and solvent containers **40** such that the solvent selection valve **36** and/or the degasser **38** are positioned upstream of the pump **22***a*. The solvent selection valve **36** can be controlled to select the modifier media **23** to be used by the system **10** from one or more solvent containers **40** and the degasser **38** can be configured to remove dissolved gases from the media modifier **23** before the media modifier **23** is pumped through the system **10**.

In exemplary embodiments, the solvent delivery system **12** can include a pre-chiller **42** disposed between an input of the pump **22***b* and a solvent container **41** such that the pre-chiller is disposed upstream of the input to the pump **22***b* and downstream of the solvent container **41**. The pre-chiller **42** can reduced the temperature of the mobile phase media **23** before it is pumped through the system **10** via the pump **22***b*. In the present embodiment, the mobile phase media **23** can be carbon dioxide. The pre-chiller can decrease the temperature of the carbon dioxide so that the carbon dioxide is maintained in a liquid state (i.e., not a gaseous state) as it is pumped through at least a portion of the system **10**. Maintaining the carbon dioxide in a liquid state can facilitate effective metering of the carbon dioxide through the system **10** at the specified flow rate.

The pumps **22***a* and **22***b* can pump the solvent **24** through the system **10** to pressurize the system **10** to a specified pressure, which may be controlled, at least in part, by the system/convergence manager **20**. In exemplary embodiments, the system **10** can be pressurized to a pressure between about 700 psi and about 18,000 psi or about 1,400 psi and about 8,000 psi. In one embodiment, the system **10** can be pressurized to a pressure of about 6,000 psi. By pressurizing the system **10** at these pressure levels (such as those pressure levels described above), the solvent stream (i.e., mobile phase) can be maintained in a liquid state before transitioning to a supercritical fluid state or near supercritical state (e.g., highly-compressed gas or compressible liquid) for a chromatographic separation in a column, which can be accomplished by raising the temperature of the pressurized solvent stream.

The sample delivery system **14** can select one or more samples to be passed through the system **10** for chromatographic separation and detection. The sample delivery system **14** can include a sample selection and injection member **44** and a multi-port valve **45**. The sample selection and injection member **44** can include a needle through which the sample can be injected into the system **10**. The multiport valve **45** can be configured to operatively couple the sample selection and injection member **44** to an input port of the system/convergence manager **20**.

The sample separation system **16** can receive the sample to be separated and detected from the sample delivery system **14**, as well as the pressurized solvent stream from the solvent delivery system **12**, and can separate components of the sample passing through the system **10** to facilitate detection of the samples using the detection system **18**. The sample separation system **16** can include one or more columns **46** disposed between an inlet valve **48** and an outlet valve **50**. The one or more columns **46** can have a generally cylindrical shape that forms a cavity, although one skilled in the art will recognize that other shapes and configurations of the one or more columns is possible. The cavity of the columns **46** can have a volume that can at least partially be filled with retentive media, such as hydrolyzed silica, such as C_8 or C_{18}, or any hydrocarbon to form the stationary phase of the system **10** and to promote separation of the components of the sample. The inlet valve **48** can be disposed upstream of the one or more columns can be configured to select which of the one or more columns **46**, if any, receives the sample. The outlet valve **50** can be disposed downstream of the one or more columns **46** to selectively receive an output from the one or more columns **46** and to pass the output of the selected one or more columns **46** to the detection system **18**. The columns **46** can be removably disposed between the valves **48** and **50** to facilitate replacement of the one or more columns **46** to new columns after use. In some embodiments, multiple sample separation systems **16** can be included in the system **10** to provide an expanded quantity of columns **46** available for use by the system **10** (FIG. **4**).

In exemplary embodiments, the sample separation system **16** can include a heater **49** to heat the pressurized solvent stream **24** prior and/or while the pressured solvent stream **24** passes through the one or more columns **46**. The heater **49** can heat the pressurized solvent stream to a temperature at which the pressured solvent transitions from a liquid state to a supercritical fluid state so that the pressurized solvent stream passes through the one or more columns **46** as a supercritical fluid.

Referring again to FIG. **2**, the detection system **18** can be configured to receive components separated from a sample by the one or more columns **46** and to detect a composition of the components for subsequent analysis. In an exemplary embodiment the detection system **18** can include one or more detectors **51** configured to sense one of more characteristics of the sample components. For example, in one embodiment, the detectors **51** can be implemented as one or more photodiode arrays.

The system/convergence manager **20** can be configured to introduce a sample from the sample delivery system **14** into the pressurized solvent stream flowing from the solvent delivery system **12** and to pass the solvent stream and sample to the sample separation system **16**. In the present embodiment, the system/convergence manager **20** can include a multiport auxiliary valve **52** which receives the sample injected by the sample delivery system **14** through a first inlet port and the pressurized solvent stream from the solvent delivery system **12** through a second inlet port. The auxiliary valve **52** can mix the sample and the solvent stream and output the sample and solvent stream via an outlet port of the multiport auxiliary valve **52** to an inlet port of the inlet valve **48** of the sample separation system **16**.

The system/convergence manager **20** can also be configured to control the pressure of the system **10** and to facilitate cooling, heating, and/or venting of the solvent from the system **10**, and can include a vent valve **54**, a shut off valve **56**, a back pressure regulator **58**, and a transducer **59**. The vent valve **54** can be disposed downstream of the detection system **18** can be configured to decompress the system **10** by venting the solvent from the system **10** after the solvent has passed through the system **10**. The shut-off valve **56** can be configured to disconnect the solvent supply from the inlet of the pump **22***b* of the solvent delivery system to prevent the solvent from being pumped through the system **10**. An exemplary vent valve **54** will be described in more detail below.

The back pressure regulator **58** can control the back pressure of the CO_2-based chromatography system **10** to control the flow of the mobile phase and sample through the column, to maintain the mobile phase in the supercritical fluid state (or, in some embodiments, in a near supercritical state, such as, a highly-compressed gas or compressible liquid) as the mobile phase passes through the one or more columns **46** of the sample separation system **16**, and/or to prevent the back pressure from forcing the mobile phase reversing its direction a flow through the one or more columns **46**. Embodiments of the back pressure regulator **58** can be configured to regulate the pressure of the system **10** so that the physical state of the solvent stream (i.e., mobile phase) does not change uncontrollably upstream of and/or within the back pressure regulator **58**. The transducer **59** can be a pressure sensor disposed upstream of the back pressure regulator **58** to sense a pressure of the system **10**. The transducer **59** can output a feedback signal to a processing device which can process the signal to control an output of an actuator control signal from the processing device.

In exemplary embodiments, as shown in FIG. **5**, the back pressure regulator **58** can include a dynamic pressure regulator **57**, a static pressure regulator **61**, and a heater **63**. The static pressure regulator **61** can be configured to maintain a predetermined pressure upstream of the back pressure regulator **58**. The dynamic pressure regulator **57** can be disposed upstream of the static pressure regulator **61** and can be configured to set the system pressure above the predetermined pressure maintained by the static regulator **61**. The heater **63** can be disposed downstream of the dynamic pressure regulator **57** and can be disposed in close proximity to the static pressure regulator **61** to heat the solvent stream as it passes through the static pressure regulator **61** to aid in control of the physical state of the solvent as it passes through the static pressure regulator.

In summary, an exemplary operation of the CO_2-based chromatography system **10** can pump mobile phase media **23** and modifier media **25** at a specified flow rate through the system **10** as a solvent stream (i.e., mobile phase) and can pressurize the system **10** to a specified pressure so that the solvent stream maintains a liquid state before entering the sample separation system **16**. A sample can be injected into the pressurized solvent stream by the sample delivery system **14**, and the sample being carried by the pressurized solvent stream can pass through the sample separation system **16**, which can heat the pressurized solvent stream to transition the pressurized solvent stream from a liquid state to a supercritical fluid state. The sample and the supercritical fluid solvent stream can pass through at least one of the one or more columns **46** in the sample separation system **16** and the column(s) **46** can separate components of the sample from each other. The separated components can pass the separated components to the detection system **18**, which can detect one or more characteristics of the sample for subsequent analysis. After the separated sample and solvent pass through the detection system **18**, the solvent and the sample can be vented from the system **10** by the system/convergence manager **20**.

In other embodiments, the system **10** described herein can also be used for preparatory methods and separations. Typical parameters, such as those described above, may be manipulated to achieve effective preparatory separations. For example, the system **10** described herein confers the benefit of exerting higher flow rates, larger columns, and column packing size, each of which contributes to achieving preparatory separation and function, while maintaining little or no variability in overall peak shape, peak size, and/or retention time(s) when compared to respective analytical methods and separations thereof. Thus, in one embodiment, the present disclosure provides CO_2-based chromatography systems which are amendable to preparatory methods and separations with high efficiency and correlation to analytical runs.

FIG. **6** is a cross-sectional view of an exemplary embodiment of a dynamic pressure regulator **57** along a longitudinal axis L of the dynamic pressure regulator. The dynamic pressure regulator **57** can be implemented as a valve assembly that includes a proximal head portion **72**, an intermediate body portion **74**, and a distal actuator portion **76**. The head portion **72** of the valve assembly can include an inlet **78** to receive the pressurized solvent stream and an outlet **80** through which the pressurized solvent stream is output such that the solvent stream flows through the head portion from the inlet **78** to the outlet **80**. A seat **82** can be disposed within the head portion **72** and can include a bore **84** through which the solvent stream can flow from the inlet **78** to the outlet **80** of the head.

A needle **86** extends into the head portion **72** from the body portion **74** of the valve assembly through a seal **88**. A position of the needle **86** can be controlled with respect to the seat **82** to selectively control a flow of the solvent stream from the inlet **78** to the outlet **80**. In exemplary embodiments, the position of the needle **86** can be used to restrict the flow through the bore **84** of the seat **82** to increase the pressure of the system **10** and can selectively close the valve by fully engaging the seat **82** to interrupt the flow between the inlet **78** and the outlet **80**. By controlling the flow of the solvent stream through the head portion based on the position of the needle **86**, the pressure of the system **10** can be increased or decreased. For example, the pressure of the system **10** can generally increase as the needle **86** moves towards the seat **82** along the longitudinal axis L and can generally decrease as the needle **86** moves away from the seat **82** along the longitudinal axis L.

The actuator portion **76** can include an actuator **90**, such as a solenoid, voice coil, and/or any other suitable electromechanical actuation device. In the present embodiment, the actuator **90** can be implemented using a solenoid having a main body **92** and a shaft **94**. The shaft **94** can extend along the longitudinal axis L and can engage a distal end of the needle **86** such that the needle **86** and shaft can form a valve member. A position of the shaft **94** can be adjustable with respect to the main body **92** along the longitudinal axis L and can be controlled by a coil (not shown) of the main body **92**, which generates a magnetic field that is proportional to an electric current passing through the coil and a load applied to the shaft. The electric current passing through the coil can be controlled in response to an actuator control signal received by the actuator **90**. In some embodiments, the actuator control signal can be a pulse width modulated (PWM) signal and/or the actuator control signal can be determined, at least in part, by the feedback signal of the pressure transducer **59**.

The position of the shaft **94** can be used to move the needle **86** towards or away from the seat **82** to increase or decrease pressure, respectively. In exemplary embodiments, a position of the shaft **94**, and therefore a position of the needle **86** with respect to the seat **82** can be controlled and/or determined based on an amount of electric current flowing through the solenoid. For example, the greater the electrical current the closer to the needle **86** and shaft **94** are from the seat and the lower the pressure is in the system **10**. The relationship between a position of the shaft **94** and the electric current flowing through the coil can be established through characterization of the actuator **90**. The force imposed by the load on the solenoid can be proportional to the magnetic field. Similarly, the magnetic field can be proportional to the electric current flowing through the coil of the solenoid. For embodiments in which the actuator control signal is implemented as a PWM control signal, the pressure through the pressure regulator **57** (e.g., force balance between needle **86** and shaft **94**) can be set by a correlation to the duty cycle of the PWM control signal, e.g., a percentage of the duty cycle corresponding to an "on" state.

The force imposed by the actuator **90** to set the pressure through the pressure regulator **57** can be manipulated for force control purposes by inclusion of a compressed spring **96**. Spring **96** is compressed by collar **98** to apply a normalizing force to the actuator **90** through an exterior shaft liner **100**. This normalizing force assists in providing a linear load force throughout the cycle of the actuator **90**. In general, actuator **90** has a negative spring rate, such that shaft **94** when the actuator **90** is in an inactive state is forced in a direction opposite of outlet **80** (i.e., towards the end of the device labeled B), such that the force reduces as the solenoid stroke increases. To compensate for this force, compressed spring **96** applies a pressure to shaft **94** to counterbalance the negative spring rate of the actuator **90**. In some embodiments, the spring rate selected for compressed spring **96** has a value that not only counterbalances but also applies a positive spring rate such that shaft **94** moves towards the end of the device labeled A.

To regulate pressure through device **57** from inlet **78** to outlet **80**, the needle **86** and seat **82** are carefully positioned relative to one another. A calibrated position between the needle **86** and seat **82** is set at the position when the needle **86** first engages the bore **84** of the seat **82** to stop the flow of solvent. In general, care is taken to set this calibrated position, such that the needle **86** will not be jammed into the bore **84** during operation of pressure regulator **57**. It is believed that prevention or at least minimization of the needle being jammed into the bore will extend the life of the pressure regulator and/or increase the working lifetime prior to a maintenance event.

During the lifetime of the pressure regulator **57**, components, such as, for example the needle **86** or the seat **82** can become worn. These components may be replaced in maintenance events. After the maintenance event, the needle and seat need to be placed back into the calibration position.

Exemplary embodiments of the pressure regulator **57** include a calibration collar **110** secured to the shaft **94** to automatically (e.g., mechanically) reset the calibration position. That is, the calibration collar **110** applies a force on shaft **94** to lock further extension of the shaft **94**. When the calibration collar **110** is secured onto shaft **94**, a maintenance provider or user merely needs to position the shaft **94** in physical contact with the distal end of the needle and lock the calibration collar to mechanically set needle **86** relative to the seat **82** in the calibrated position.

To apply the force, the calibration collar **110** includes a spring **112** and two locking mechanisms **114** and **116**. Locking mechanism **114** holds the calibration collar **110** to the exterior liner **100** of the shaft **94**, whereas locking mechanism **116** grips the distal end **118** of the shaft **94** to clamp or lock the extended position of the shaft **94** to prevent jamming of the needle **86** into the seat **82**. In the embodiment shown in FIG. **6**, the locking mechanisms include fasteners **120** and **122** to secure a housing **124** forming the calibration collar **110** to the actuator **90**.

During a maintenance event, the actuator **90** is inactivated (i.e., no signal is applied to drive the solenoid) and the flow of solvent is stopped. The needle **86** and seat **82** are in the calibrated position at the start of the maintenance event. That is, the needle **86** engages seat **82** to block bore **84**. The calibration collar **110** attached to the shaft **94** as shown in FIG. **6** holds the needle and seat in this calibrated position. To obtain access to the distal end of the needle **86** and potentially to the seat, shaft **94** needs to be pulled back towards end B. In the calibration collar's configuration with both fasteners **120** and **122** secured, alignment of the needle **86**, seat **82**, and shaft **94** is maintained. However, to release this secured position, the user merely needs to loosen fastener **120** to release the grip of locking mechanism **116** from the distal end **118** of the shaft **94**. The fastener **122** remains securely tightened or closed such that locking mechanism **114** continues to hold the housing **124** of the calibration collar **110** to the exterior liner **100**. However, distal end **118** of the shaft **94** is free to move to allow access to the needle/seat for maintenance. At the conclusion of the maintenance event, the user places the proximal end **126** of the shaft **94** in contact with the needle **86** and tightens fastener **120** to reposition the needle **86** relative to the seat an in the calibrated position.

FIG. **7**A is an exploded view of calibration collar **110**. In FIG. **7**A, a portion of locking mechanism **114** (e.g., clamp **114**) is shown in an unfastened state to show additional details of the interior of the calibration collar **110**. The calibration collar **110** is formed from housing **124**, typically manufactured from a metal, such as, for example, stainless steel or aluminum. The spring **112** (shown in FIG. **6** but not shown in FIG. **7**A) is disposed at least partially within a first end **130** of the housing. Locking mechanism **114** is disposed on the opposite end or the second end **132** and between locking mechanism **114** and the first end **130** is locking mechanism **116** (e.g., clamp **116**). The spring **112** preloads and automatically positions the needle **86** to the seat **92**. In some embodiments in which the needle is manually positioned, spring **112** can be removed.

A channel **134** is defined within housing **124** and the size of channel **134** is configured to accept at least a portion (such as, for example the distal end **118** and a portion of the exterior liner **100**) of the shaft **94**. The locking mechanism **114** surrounds channel **134** and is sized to receive the exterior liner **100**. The locking mechanism **114** includes a base portion **135** and a top portion **136**. When fasteners **122** are installed and tightened within openings **140**, the locking mechanism is configured to secure base portion **135** to top portion **136** in a locked position, in which the housing **124** is held to the exterior liner **100**. In embodiments, surface **138** defining a wall of the channel through locking mechanism **114** can be textured to apply a frictional force to further secure the calibration collar **110** to the actuator **90**. Applied textures can include raised bumps, ribs, or grooves.

Locking mechanism **116** is also shown in an unfastened state in FIG. **7**A. Fastener **120** secures locking mechanism **116** in a closed position by forcing clamping portions **144** and **146** together at free ends **150** and **152**. As shown in FIG. **7**A, each of the clamping portions **144** and **146** are integrally formed with the housing. In addition, base portion **135** of locking mechanism **114** is also integrally formed with the housing. In another embodiment, clamping portions **144** and **146** can be replaced with a two piece design similar to that shown by base portion **135** and top portion **136**. In this two-piece embodiment shown in FIG. **7**B, fastener **120** as shown in the embodiment of FIG. **7**A is replaced with two fasteners **122'** and portions **144** and **146** as shown in the embodiment of FIG. **7**A are replaced with a unitary piece **145** which is separate from base portion **135**. Springs **147** can be used to aid in separating piece **145** when fasteners **122'** are loosened or removed.

Locking mechanisms **114** and **116** can be implemented in numerous different configurations. For example, FIG. **8** shows an another calibration collar **110'** with locking mechanisms **114'** and **116'** each of which are integrally formed with housing **124'** and secured with a single fastener in each of openings **140'**. A cross-sectional view of calibration collar **110'** is shown in FIG. **9**. In FIG. **9**, calibration collar **110'** is secured to actuator **90** through shaft **94** and exterior liner **100**.

In other embodiments, figures not shown, the locking mechanism **114** and/or **116** can be electromechanical locking assemblies in which an applied electric signal is used to open and close the mechanisms.

FIGS. **10***a* and **10***b* show an exemplary embodiment of shaft **94**. As shown in FIGS. **6** and **9**, shaft **94** lies within exterior liner **100** and is the portion of the actuator **90** that contacts needle **86**. The proximal end **126** of shaft **94**, when in use for pressure regulation, contacts the needle **86** to apply a force to the needle to change its position. In embodiments, the distal end **118** of the shaft **94** is secured within one of the exemplary calibration collars disclosed herein. The exterior surface of the distal end **118** can include a texture, such as the texture shown in FIGS. **10***a* and **10***b* to provide further grip or friction between locking mechanism **116** and the distal end **118**. In addition to the exterior surface of the distal end **118** being textured, the interior surface **133** of a wall defining the channel **134** through locking mechanism **116** can also be textured. Applied textures can include raised bumps, ribs, grooves, or the like.

FIGS. **11** and **12** show flowcharts of methods in which the exemplary calibration collars of the present disclosure are utilized. FIG. **11** illustrates an exemplary method **200** of replacing a needle or a seat in a pressurized flow device, such as, for example a pressure regulator in a CO_2-based chromatography system. FIG. **12** illustrates an exemplary method **300** of setting and maintaining a calibrated position between a needle and a seat in a pressurized flow system, such as for example a CO_2-based chromatography system operated at or near supercritical conditions.

Referring to FIG. **11**, method **200** includes the following steps: providing the calibration collar, such as, for example collar **110** or **110'**, with the first securing mechanism (e.g. locking mechanism) in the locked position and the second securing mechanism (e.g., locking mechanism) in the closed position to secure and grip the calibration collar to the shaft of the actuator so that the needle and seat are in a calibrated position—step **210**; moving the second securing mechanism from the closed position (e.g., fastener tightened or secured) to an open position (e.g., fastener loosened or removed) to release the grip of the calibration collar from an interior extendable section of the shaft (e.g., shaft **94**)—step **220**; moving the shaft (e.g., proximal end of the shaft) to obtain access to the needle—step **230**; replacing at least one of the needle **86** or the seat **82**—step **240**; positioning the shaft to be in physical contact with an end of the needle **86** or replaced needle—step **250**; and moving the second securing mechanism from the open position to the closed position (e.g., tightening fastener or securing clamp through electromechanical means) to grip the interior extendable section of the shaft and position the replaced needle or seat in the calibrated position—step **260**.

There are numerous advantages provided by the above method. For example, the method provides for consistent calibration between the needle and the seat after maintenance events or upon start-up of a dormant system. That is, the calibration collar **110**, secured to the exterior liner **100** and the interior shaft **94** of the actuator **90** mechanically set the position of the needle relative to the seat such that the calibration position is consistently provided after each maintenance or start-up event. In addition, as locking mechanism **114** secures the calibration collar to the actuator **90** and locking mechanism **116** grips the shaft **94** to set and maintain the calibration position, a user's interaction with the calibration collar **110** and associated pressure regulator **57** after maintenance is complete is merely to tighten or secure locking mechanism **116**. As a result, shut down time associated with maintenance events is minimized.

In addition to the above advantages, the method **200** in certain embodiments, can include features which improve efficiency and further limit a user's interaction. For example, method **200** can be implemented for use with one or more electromechanical locking assemblies used to secure or close locking mechanisms **114** and/or **116**. Method **200**, in these embodiments, can further including one or more of the following features. Release of the securing or locking mechanisms can occur automatedly without user input upon the actuator being placed in a non-operating position (e.g., no signal supplied to the actuator, no flow of solvent through the regulator). The locking mechanism **116** can move from the closed position to an open position automatically at each start-up event of the regulator **57**—once again without user input. In addition, it is noted that step **250** occurs automatically when spring **112** is included in the calibration collar **110**, which also includes locking mechanisms **114** and **116**. In embodiments which do not include spring **112**, a user would manually position the shaft to be in physical contact with an end of the needle **86** or replaced needle.

Referring to FIG. **12**, method **300**, a method of setting and maintaining a calibrated position between a needle and a seat in a pressurized flow system, is illustrated. Exemplary method **300** includes the steps of: placing the calibration collar, such as collar **110** on a first end of the shaft of an actuator such that the channel **134** defined in the housing **124** at least partially surrounds the distal end portion **118** of the shaft—step **310**; securing the first securing mechanism (e.g., locking mechanism **114**) of the calibration collar to the shaft to hold the housing **124** to the shaft **94** and to position the first securing mechanism in the locked position—step **320**; positioning the needle **86** relative to the seat **82** to set the calibrated position (e.g., needle **86** first engages seat **82** to block bore **84**)—step **330**; positioning a second end of the shaft of the actuator to be in physical contact with the needle (e.g., placing the proximal end **126** of the shaft in contact with the distal end of the needle)—step **340**; and securing the second securing mechanism (e.g. locking mechanism **116**) of the calibration collar to the shaft to maintain the calibrated position and to position the second securing mechanism in the closed position—step **350**. It is noted that step **330** occurs automatically when spring **112** is included in the calibration collar **110**, which also includes locking mechanisms **114** and **116**. In embodiments which do not include spring **112**, a user would manually position the shaft to be in physical contact with an end of the needle **86** or replaced needle.

Method **300** can also additionally include steps to account for a maintenance event—such as, for example, a replacement of a needle or seat. These steps return the needle at the conclusion of the maintenance event to the calibration position—without the user having to manual reset or find the calibration position. Instead, the user merely tightens or closes the second securing mechanism after maintenance is complete to return the components of the regulator **57** to the calibrated position.

For example, method **300** can further include the following steps: moving the second securing mechanism from the closed position to an open position to release the grip of the calibration collar; moving the second end (e.g., proximal end **126**) of the shaft to obtain access to the needle (e.g., to obtain access for a maintenance event); positioning the second end of the shaft to be in physical contact with the exposed end (e.g., distal end) of the needle; and moving the second securing mechanism from the open position to the closed position to grip the shaft and to return the needle and seat to the calibrated position.

While exemplary embodiments have been described herein, it is expressly noted that these embodiments should not be construed as limiting, but rather that additions and modifications to what is expressly described herein also are included within the scope of the invention. Moreover, it is to be understood that the features of the various embodiments described herein are not mutually exclusive and can exist in various combinations and permutations, even if such combinations or permutations are not made express herein, without departing from the spirit and scope of the technology.

The invention claimed is:

1. A calibration collar for automatically setting a position of a needle to a seat in a pressurized flow system including an actuator positioned to drive the needle relative to the seat, the actuator comprising a shaft including an exterior liner and an interior extendable section, the calibration collar comprising:
- a housing including a first end and a second end, the housing defining a channel sized to accept at least a portion of the shaft of the actuator;
- a first securing mechanism positioned at the second end of the housing and surrounding the channel, the first securing mechanism, when in a locked position, holds the housing to the exterior liner of the shaft;
- a second securing mechanism, independent of the first securing mechanism, the second securing mechanism when in a closed position, grips at least a portion of an external perimeter surface of the interior extendable section of the shaft to clamp the housing to the shaft; and
- a spring disposed at least partially in the first end of the housing and extending into the channel to apply a known load on the shaft when the shaft is seated in the housing.

2. The calibration collar according to claim **1**, wherein the first securing mechanism is a clamp.

3. The calibration collar according to claim **1**, wherein the second securing mechanism is a clamp.

4. The calibration collar according to claim **1**, wherein the second securing mechanism is positioned between the first securing mechanism and the first end of the housing.

5. The calibration collar according to claim **2**, wherein the clamp comprises a base portion integrally formed with the housing and a top portion secured to the base portion with two fasteners.

6. The calibration collar according to claim **3**, wherein the clamp comprises a base portion integrally formed with the housing and a top portion secured to the base portion with two fasteners.

7. The calibration collar according to claim **3**, wherein the clamp comprises a first clamp portion integrally formed with the housing and having a first free end and a second clamp portion integrally formed with the housing and including a second free end, the second free end of the second clamp portion opposing the first free end of the first clamp portion, the first and second clamp portions being secured together with a fastener.

8. The calibration collar according to claim **1**, wherein the housing is formed at least in part of stainless steel.

9. The calibration collar according to claim **1**, wherein the housing is formed at least in part of aluminum.

10. The calibration collar according to claim **1**, wherein at least a portion of a surface of the housing defining the channel is textured to facilitate gripping of at least a portion of an external perimeter surface of the interior extendable section of the shaft of the actuator when the second securing mechanism is in the closed position.

11. The calibration collar according to claim **10**, wherein the texture applied comprises one or more of radial grooves, raised bumps, or raised ribs.

12. The calibration collar according to claim **1**, wherein the second securing mechanism comprises a electromechanical locking assembly.

13. A method of replacing at least one of a needle or a seat in a pressurized flow device, the method comprising:
- providing the calibration collar of claim **1**, with the first securing mechanism in the locked position and the second securing mechanism in the closed position to secure and grip the calibration collar to the shaft of the actuator in an operating position in which the needle and the seat are in a calibrated position;
- moving the second securing mechanism from the closed position to an open position to release the grip of the calibration collar from the interior extendable section of the shaft;
- moving the shaft to obtain access to the needle;
- replacing at least one of the needle or seat;
- positioning the shaft to be in physical contact with an end of the needle or a replacement needle; and
- moving the second securing mechanism from the open position to the closed position to grip the interior extendable section of the shaft and position the replaced needle or seat in the calibrated position.

14. The method of claim **13**, wherein moving the second securing mechanism from the closed to the open position comprises releasing a clamping mechanism.

15. The method of claim **14**, wherein releasing a clamping mechanism comprises loosening a fastener of the clamping mechanism.

16. The method of claim **14**, wherein releasing a clamping mechanism comprises electromechanically releasing the clamping mechanism.

17. The method of claim **13**, wherein moving the second securing mechanism from the open position to the closed position comprises activating a clamping mechanism.

18. The method of claim **17**, wherein activating the clamping mechanism comprises tightening a fastener of the clamping mechanism.

19. The method of claim **17**, wherein activating the clamping mechanism comprises electromechanically closing the clamping mechanism.

20. The method of claim **16**, wherein releasing the clamping mechanism occurs automatedly without user input upon the actuator being placed in a non-operating position.

21. The method according to claim **20**, wherein moving the second securing mechanism from the open position to the closed position occurs automatedly.

22. The method according to claim **13**, wherein moving the second securing mechanism from the open position to the closed position occurs automatedly at each start-up event of the pressurized flow device.

23. A method of setting and maintaining a calibrated position between a needle and a seat in a pressurized flow system including an actuator positioned to drive the needle relative to the seat, the method comprising:

placing the calibration collar of claim **1** on a first end of the shaft of the actuator such that the channel defined in the housing at least partially surrounds an end portion of the shaft;

securing the first securing mechanism of the calibration collar to the shaft to hold the housing to the shaft and to position the first securing mechanism in the locked position;

positioning the needle relative to the seat to set the calibrated position;

positioning a second end of the shaft of the actuator to be in physical contact with an exposed end of the needle; and

securing the second securing mechanism of the calibration collar to the shaft to grip the external perimeter surface of the extendable section of the shaft to maintain the calibrated position and to position the second securing mechanism in the closed position.

24. The method of claim **23**, further comprising:

moving the second securing mechanism from the closed position to an open position to release the grip of the calibration collar from the shaft;

moving the second end of the shaft to obtain access to the needle;

positioning the second end of the shaft to be in physical contact with the exposed end of the needle; and

moving the second securing mechanism from the open position to the closed position to grip the shaft and to return the needle and the seat in the calibrated position.

25. The method of claim **23**, wherein positioning the needle relative to the seat to set the calibrated position occurs automatically.

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